

Testimony of Richard F. Reidy, Assistant Professor of Materials Science and Engineering, University of North Texas on December 5, 2003
U.S. House of Representatives' Committee on Science
"Nanotechnology Research and Development: The Biggest Little Thing in Texas"

Introduction

Nanotechnology will remain an extremely fertile research arena for the foreseeable future. It is the eventual progression of man's quest to control the basic building blocks of our world. The Apollo program expressed our desire to journey beyond Earth; nanotechnology evinces our curiosity preceding the microscopic. Like the space program, the world of the ultra-small can spur the imagination and vocations of budding scientists. Fostering this resource is critical to the future advancement of nanotechnology. Creating the "destiny of discovery" that the Lunar Landing evoked must be a parallel mission of the National Nanotechnology Initiative as we can ill-afford to make this a race for the select few. The National Science Foundation has long held that K-12 outreach was a critical element of academic research. Programs to cultivate youth interest should be as creative and fresh as our research. Directing new talent into science and engineering will provide the researchers necessary to meet the ever-expanding challenges in nanotechnology.

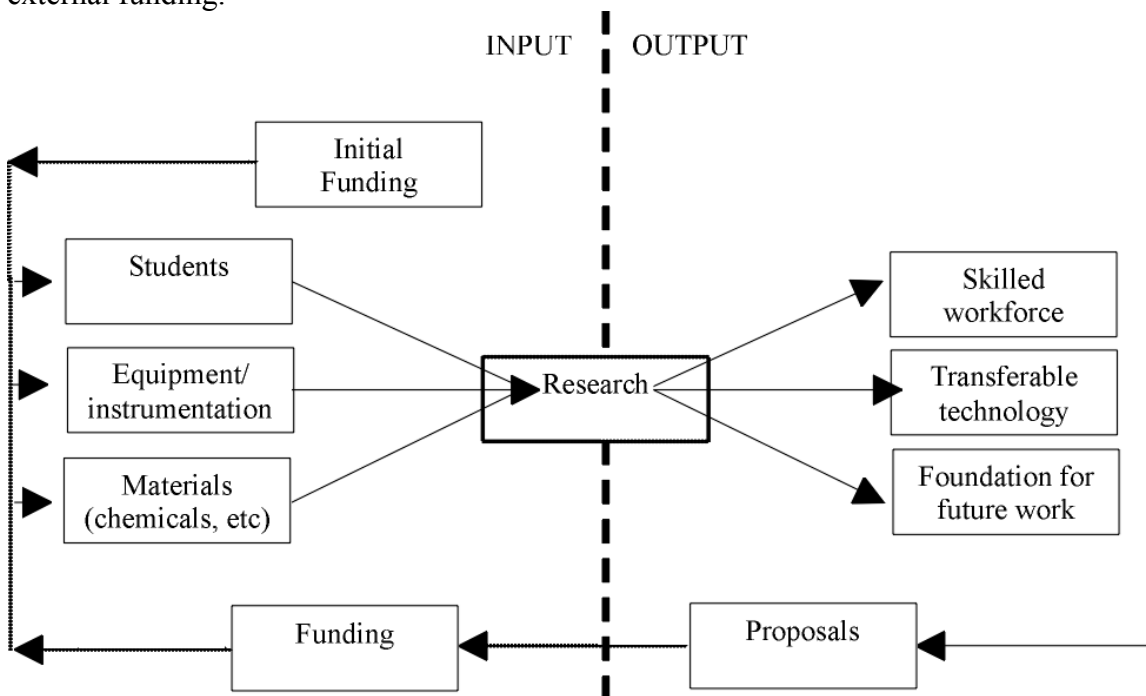
What new advances should we expect from nanotechnology? The "possible" of a few years ago has now become reality. I believe that the history of integrated circuits points to an amazing future. The semiconductor industry has repeatedly met the lofty expectations of Moore's Law (i.e., the number of transistors in a chip double every 1-2 years) despite facing extremely difficult issues with each generation of microchip. The power of personal computers exemplify this advancement: the Intel 486, the premier PC chip just over a decade ago, contained approximately 1.2 million transistors while the current Pentium 4 has over 42 million. I have been fortunate to be a member of the International Technology Roadmap for Semiconductors (the organization that plots development and expectations of future technology requirements), and I marvel at the planning and knowledge breadth that created this record of success. While many issues loom within the next decade as potential "show stoppers" to the progress of continued microchip development, past performance and sheer mass of talent will likely overcome these issues.

The discovery and development of carbon nanotubes offer an additional hopeful scenario for the progression of nanotechnology. In less than a decade, these nanometer scaled structures have been studied for a wide range of applications crossing many disciplines: high strength composite materials, nanowires, artificial kidneys, chemical weapons sensing, solar energy, and non-volatile memory. The breadth of this research highlights the need for cross-disciplinary nanotechnology research teams and the cooperative efforts of industry, government, and universities.

University-based research programs differ somewhat from industry due to the graduation of researchers and funding cycles of 1-4 years. These aspects necessitate a critical need for initial kickoff funding. The next section describes this process.

Summary of University Research Requirements and Output Dependencies

The schematic below is an abbreviated outline of nanotechnology research requirements and potential outcomes. All research of merit must have some initial funding to pay students, buy materials and maintain equipment. Excellent ideas are “grounded” without student researchers, appropriate equipment and instrumentation, and working materials. In the past, most Federal agencies required some threshold of previous work to consider a program for funding. Because much of the nanoworld is unexplored, this burden of proof has lessened considerably. This “lower bar” permits rapid testing of ideas, but increases the risk of these ventures. To account for this risk, many nanotechnology proposals are funded as one-year exploratory grants. While exploratory grants will support many strong research ideas, many more will scramble for internal or other sources of funding to initiate research. Research institutions should be encouraged to provide sufficient funding for researchers to overcome the “proof of concept” burden necessary to garner external funding.



Funding for equipment and instrumentation presents another issue. The study of the very small requires specialized and often expensive instrumentation. While some large well-funded institutions can often support purchases of six and seven figure capital equipment, smaller institutions must rely on federal and state outlays to support these purchases. The recent work by Rep. Burgess to support the purchase of a high-resolution transmission electron microscope here at UNT is an example of such an outlay. Major research instrument funding from the National Science Foundation is highly competitive, and strong proposals have often gone unfunded. It is critical that financial support of major equipment purchases be accessible to all institutions with a proven need. Without accessibility to specialized instrumentation, nanotechnology will become the province of only a few universities. To summarize, issues of concern are:

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- initial funding to “kickoff” research and prove basic concepts
- accessibility of instruments necessary to develop nano-scaled materials and systems.

Responses to Questions

How significant of an impact will nanotechnology have on U.S. economic growth and job creation in the coming decades? In what industry areas will the impact be most dramatic? What challenges exist that may slow or limit the growth and influence of nanotechnology?

Advancements in nanoscience will permit faster, smarter, and more selective techniques to overcome both mundane and exotic problems. Powders that rapidly detoxify chemical weapons, frictionless surfaces, cancer drugs that repair defected gene sequences, and clothing that regulates skin temperature are all topics of research interest. From process control to smaller and smarter computers, few automated industries will not benefit from nanotechnology advancements. However, the industries most likely to see dramatic improvements are electronics and biotechnology.

Recent estimates suggest that 1 million jobs will result from applications of nanotechnology. Over the last four years, venture capitalists have invested over \$900 million in nanotechnology--\$386 million in 2002. The current environment is ripe for the creation of nanotechnology startup ventures. In addition to its focus on nanotechnology research, the newly formed Center for Advanced Research and Technology (CART) can become an incubator for small technology companies. In this role, CART can foster technology development and job growth in the North Texas region.

Limits to Nanotechnology Growth

Effective growth can be managed by balancing support of basic, applied, and engineering research. While basic research will likely remain the province of universities and national laboratories, more applied efforts must involve active contributions from industry. Universities must be open to non-traditional collaborations to encourage the infusion of industry-specialized knowledge and to ease technology transfer. As industry continues to lower the prominence of the “r” in research and development, it is incumbent on government and industrial consortia to support universities as R and D alternatives and to fund university purchases of “dual use” equipment to expand the capabilities of local industries.

It is critical to develop and maintain a trained workforce. If demand for researchers and technologists exceeds our supply, then growth will slow or industry will seek talent from outside the US. Neither alternative is in the best interest of the U.S. We should prepare for this coming need as the nation did in the late 1950’s and early 1960’s during the space race.

What in your experience are the best practices to help facilitate the transfer of basic research results to industry? To what extent has UNT partnered with industry on nanotechnology research and development challenges, and how can such collaborations be made more effective?

Transfer of Basic Research to Industry

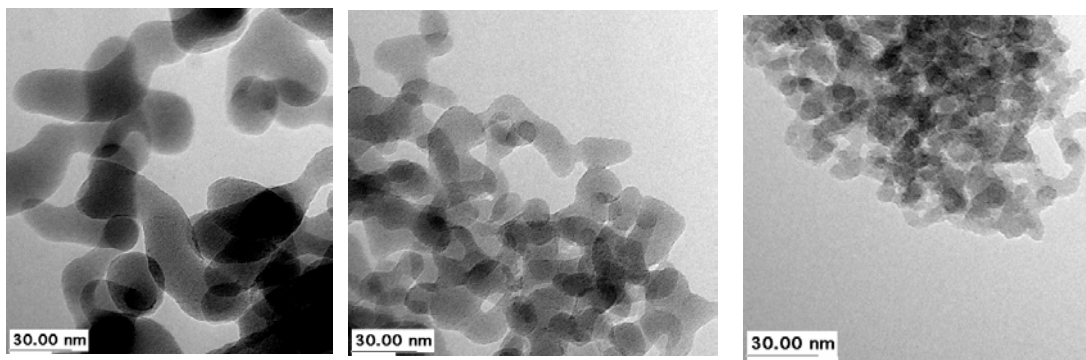
Some universities have well-staffed industrial liaison organizations to market the intellectual wares of their faculty. This model has led to many valuable patent licensing agreements and startup companies. For universities without such infrastructure, this business model may not be practical. Integrated joint research ventures in which basic and applied research are conducted at the university and product development remains with the industrial partner may be more suitable for many universities. Contracts detailing confidentiality, intellectual property rights, and licensing agreements permit sharing of information and experience that will greatly assist the university researchers. Planning and status meetings should include as many participants as possible including graduate researchers. These same practices would be of effective in business incubators.

UNT Partnerships with Industry

UNT has initiated nanotechnology collaborations with a range of industrial partners: Carbon Nanotechnologies Incorporated, Kraft Foods, Clarisay, Texas Instruments, as well as industrial consortia such as Semiconductor Research Corporation and International Sematech.

My work with colleagues Dr. Dennis Mueller of UNT, Dr. Moon Kim of UT-Dallas, and Dr. Phil Matz of Texas Instruments focuses on the nanoscale properties of integrated circuit insulators and the development of new insulator materials with controlled nanometer-sized structures. This work is supported by the National Science Foundation "Grant Opportunities for Academic Liaison with Industry" (GOALI) program. In addition to funding from NSF, Texas Instruments (TI) has agreed to provide substantial in-kind support including access to instrumentation and processed wafers. As both a co-investigator and TI liaison, Dr. Matz, meets with both students and faculty regularly to collaborate on research topics and facilitate experiments at TI facilities. All of the investigators have been granted access to relevant facilities, and TI has provided me with an office to stage and coordinate experiments. This arrangement efficiently integrates the need of Texas Instruments to conduct long term research and provides UNT students the opportunity to work on very practical problems and to directly interface with industry.

Examples of our work on the nanoscale: The electron microscopy images below (all are of the same type of SiO_2 insulator material) illustrate our ability to control structure and, consequently, to impart desired properties to these materials.



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Has federal support for your research been effective at helping UNT achieve its goals? How might Congress strengthen the structure, funding levels, and focus of the National Nanotechnology Initiative?

Federal Support to Achieve UNT Goals

In FY2003, UNT received over \$760,000 in federal nanotechnology research funding and \$3.1million from the Department of Defense for the establishment of the Center of Advanced Research and Technology. These funds produced very interesting results and have leveraged additional support from other agencies. It is the goal of our university to play a major role in the development of nanotechnology and the subsequent creation of jobs in the North Texas region. The formation of CART and the purchase of a high-resolution transmission electron microscope will permit UNT to study materials on the atomic scale, collaborate with local industry, and incubate new technology companies.

Congressional Strengthening of Structure, Funding Levels and Focus of NNI

Funding for nanotechnology will need to increase as new promising avenues of research are revealed. Periodic assessment of how budgets are meeting needs, especially in the areas of outreach, will be necessary. While the NNI has included workforce preparation as part of its mission, there exist several key issues that affect the integration of nanotechnology course material into current K-12 curriculum¹:

- Current budget constraints at state and local levels require that changes in curriculum would inflict cost increases on those who are already facing funding cutbacks. Such changes should be at a minimum revenue neutral; therefore, funding of new materials or teacher education should be absorbed by NNI (under the auspices of Centers of Excellence or NIRT grants).
- Likewise, compensation to teachers for their involvement in nanotechnology summer workshops should reflect these recent restrictions in funding. Simply put, we must make it financially worth their time to participate. Teachers are often seriously underpaid, and these programs need incentives to induce the necessary levels of participation.
- A large fraction of math and science teachers does not have degrees in their subject area. The average teacher has 15 years experience; therefore, most teachers have not had formal science training since 1988. It is critical that teacher outreach programs involve language and context commensurate with these issues. These are experienced professionals who are willing to learn, but, in many cases, may need some leveling materials in the initial stages. Being cognizant of our outreach audience's background is critical to effectively convey the possibilities of nanotechnology research. It is our goal to infuse an enthusiasm to teachers that will carry over to their students.
- One of the best ways to influence career choices of young people is through summer job experiences. As a product of a NSF summer science program, I can attest to the

¹ Many of these discussion points are described in "Extending Outreach Success for the National Nanoscale Science and Engineering Centers – A Handbook for Universities". James G. Batterson of the National Nanotechnology Coordinating Office, January 2, 2002.

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value of my first real experience with research. Summer science programs similar to the NSF REU (Research Experience for Undergraduates) should be instituted at universities across the nation. Programs will have specialties based on their research. Students will be responsible for room and board although financial aid should be available.

I believe that there are simply not enough Nanotechnology Centers of Excellence to conduct nationwide outreach programs. Extending this responsibility to other nanotechnology grant holders would expand the scope of the program. To avoid conflicting motivations, additional funds should be available for outreach for non-center grant holders. The funding of these education programs should be evaluated separately from the research aspects of the grants and could be funded after the research grants expire. Outreach programs are difficult to set up and critical to development of a trained workforce; therefore, existing programs should be nurtured and supported without interruptions if possible.

Is the U.S. education system currently producing an adequate number of people with the skills needed to conduct research in nanotechnology and to work in industry on the commercialization of nanotechnology applications? What is the longer-term outlook for the nanotechnology workforce, and what changes, if any, should be made to the current education system to ensure these workforce needs are met?

Capabilities of US Educational Institutions to Meet Future Needs

At present, elementary, secondary, community college and university systems are not producing graduates with the skill sets to meet nanotechnology challenges. In part this failure is a hangover from the 1990's—business degrees and computer science were preferred over natural science and engineering degrees as means to rapid wealth. The pendulum will no doubt swing back toward engineering and natural sciences; however, we lack the teachers at all levels to meet our growing need.

The current shortages in state budgets are impacting local school districts. For example, several school districts in North Texas are considering cutting back on advanced placement courses. While the pressures on local school boards are immense, such cutbacks are shortsighted and could have long term effects on math and science education. Some longer term suggestions to increase the number and improve the quality of science and engineering students:

- Federal, state, and local funding outlays are necessary to increase middle and high school math and science teachers.
- Science curriculum coordination should include personnel with research experience.
- Science and engineering doctoral students should be encouraged to teach at the secondary levels.
- University science and engineering programs should be expanded to include new areas of research.
- K through 20+ pedagogy should encourage cross-disciplinary problem solving and collaboration.

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Summary

Nanotechnology will no doubt change our world, but it presents new challenges to our educational system, our industries, and our Federal, state and local governments. Many important issues regarding the funding and value of nanotechnology must be decided by an educated and informed populace. It is the responsibility of the National Nanotechnology Initiative and its supported researchers to make new and exciting discoveries and to prepare our nation to meet the challenges of this new world.